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HVDC Links for Automatic Generation Control in a Multi-Area Interconnected Power System

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Abstract*: This research analyses how variations in multi-area power system automatic generation control (AGC) work when an HVDC system functions with an HVAC system taking into account system parameter alterations. A fuzzy logic controller serves to connect four areas through parallel HVAC/HVDC transmission link systems also referred to as asynchronous tie lines. A linear model of HVAC/HVDC becomes available for evaluation purposes while analyzing abrupt load variations in the system. The investigation uses a four-area interconnected thermal power system. A system whose dynamic performance has been improved will deliver appropriate solutions to the automatic generation control problem affecting the four-region electrical power system. The controller robustness evaluation happens through varying system parameters. The simulation output demonstrates effectiveness of this approach. Advanced Fuzzy logic controllers in MATLAB-Simulink perform dynamic system analysis both in presence of and absence of an HVDC link. The suggested system achieves better results regarding settling time and overshoot compared to the existing model.*

Keywords*: Fuzzy logic controller, HVDC link, automatic generation control, area control error, and generation rate limitation*

I. Introduction

Providing proper functionality to interconnected power systems requires automatic generation control to be considered a mandatory technological framework. The operation and control of large electrical power system control areas dependent on automatic generation control is essential for providing reliable and high-quality electric power supply. Tie-line power flow discrepancies along with frequency mismatch problems develop between areas because of area load modifications and unexpected generating unit outages and system parameter changes.

Generator power output regulation within defined control areas serves to correct lower frequency problems. Automatic generation control maintains power output from generators within specific control areas to preserve schedule frequency and interact between regions based on predetermined boundaries by adjusting generator outputs based on tie-line variations and system frequency changes as well as other defined criteria [1]. An appropriate control strategy coordinates the automatic definition of hydro gate and main stream valve operations.

Research indicates certain intelligent controllers operate this process after considering the tie line connection of the control area. Fast-acting energy storage systems including superconducting magnetic energy storage [5], battery energy storage [6], super-capacitor bank [7] etc. are capable of effectively reducing electromechanical power system oscillations through their dual functionality as energy storage units and rotor kinetic energy containers. Engineers have considered HVDC transmission links to serve as system interconnection components. Expert research has mainly dealt with power systems which include area interconnection through ac tie lines alone.

The HVDC gearbox system experienced considerable growth because it provides superior benefits than other available options regarding performance, economy and environmental impact. Several control areas benefit from minor disturbances due to the simultaneous implementation of a dc link with an HVAC connection which both enhance system dynamic performance and stability margins. The system interconnection resulted in enhancing system dynamic performance levels.

Testing takes place after the system linearization process using operational conditions while incorporating the system parameter values [6]. The actual operational parameters of systems change constantly since operating conditions shift. Various modern intelligent controllers serve as solutions to this problem. The power system demonstrates multiple characteristics with complex characteristics which make conventional control methods unable

to yield suitable solutions. Fuzzy controllers display dependable stability attributes that make them effective at handling different control complexity problems such as power system AGC operations.

The authors have created a fuzzy logic-based proportional integral (pi) controller which simulates dynamic control operations for four-area thermal power systems with parameter uncertainties attached to HVAC/HVDC parallel linkages. The simulation displays evidence to show both the effectiveness and performance of this scheme.

II. Four Area Power System

The research model features four connected power system areas which consist of equal single-stage reheat thermal turbines in each section. The four sites are connected through both HVDC transmission links and HVAC tie lines. The model presents its two-area single line diagram in Figure 1 while Figure 3 illustrates the transfer function model of a four-area power system with HVDC links. These transmission lines surpass the break-even distance between HVAC and HVDC systems therefore they qualify as long transmission lines [8].

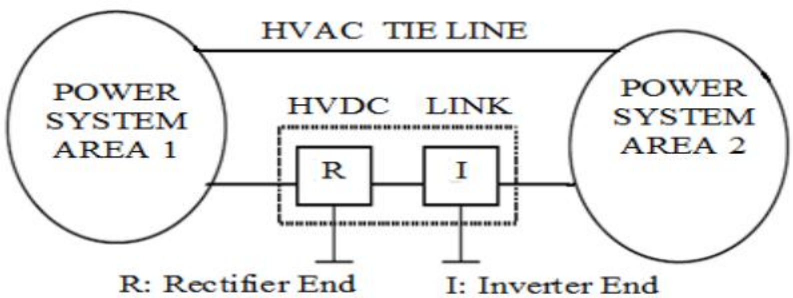

Fig 1: Single line diagram of two area power system with parallel HVAC/HVDC links

III. Fuzzy Logic Controller

Current conventional control approaches fail to solve power system problems because of power system complexity and dynamic nature of shifting loads. Recognized as one of the main approaches for designing controllers of non-linear systems is artificial intelligence-based gain scheduling. Fuzzy systems convert information from human knowledge into mathematical expressions [5]. The adoption of fuzzy set theory methods serves as a valuable supplementary tool to mathematical methods when handling power system problems. Fuzzy logic together with fuzzy set theory establishes the rules that define a nonlinear mapping.

One of the basic elements of fuzzy control contains fuzzy logic which demonstrates similarities to human thought processes while retaining distinctions from traditional logical systems. Fuzzy logic serves all contemporary industry sectors and scientific domains. Automatic generation control constitutes one of the main functions. The main task of AGC in linked power systems involves ensuring output consumption stabilization. The system analysis received its fuzzy logic controller implementation presented through Figure 2.

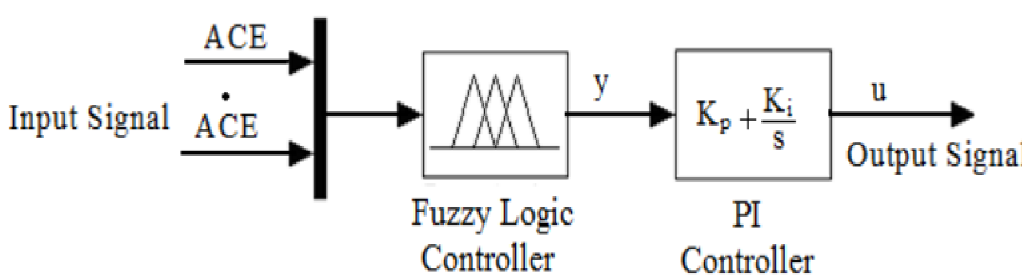

Figure 3. Structure of fuzzy logic controller

Fig 2: Structure of fuzzy logic controller

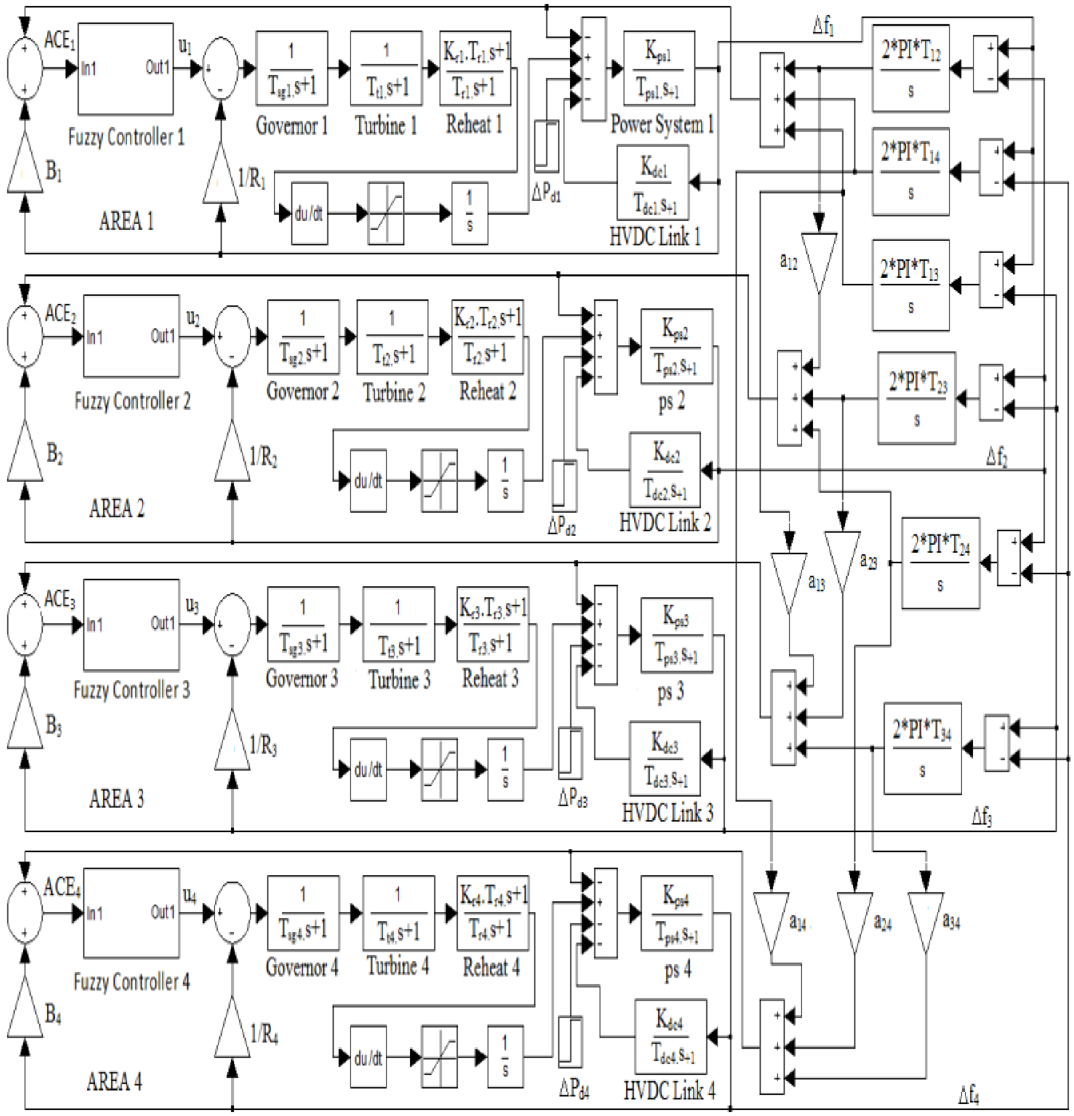

Fig 3: Transfer function model of four area interconnected power system

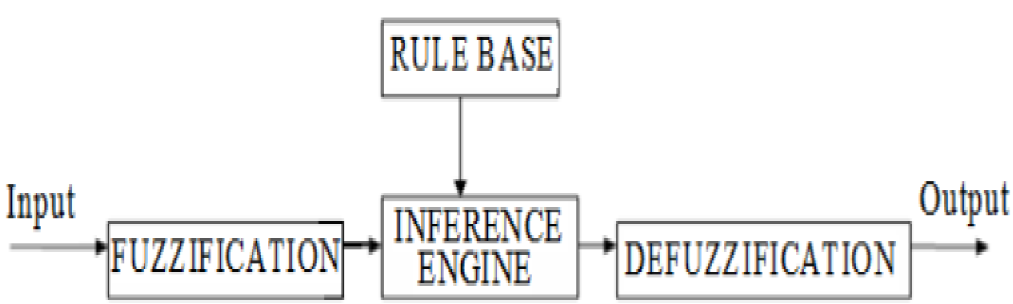

Fig 4: Components of a fuzzy controller

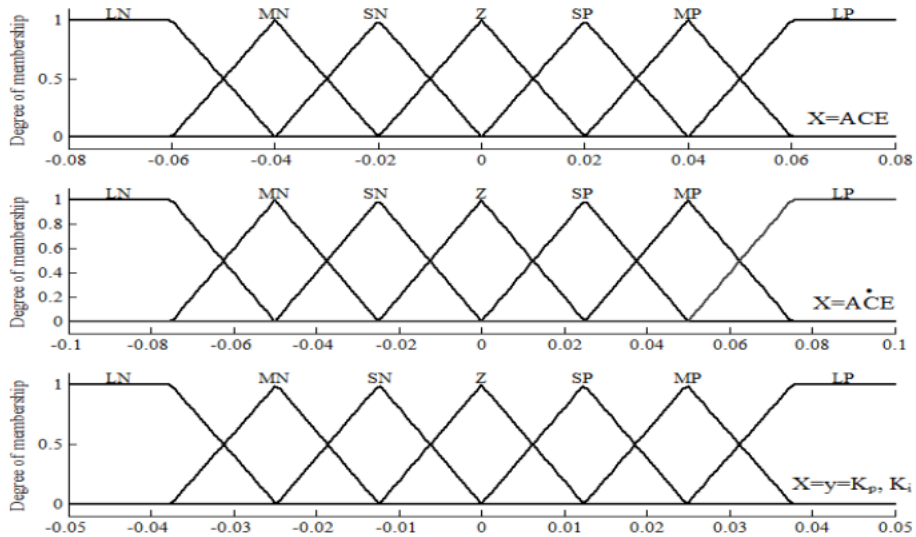

Fig 5: Membership functions used in the study

IV. Simulation Results

The simulation results indicate that adding an HVDC link alongside an HVAC link results in shorter settling times and diminished peak overshoots as depicted in Figures 6, 7, and 8. Data from the simulation shows that HVDC as an AC control system meets requirements for AGC systems.

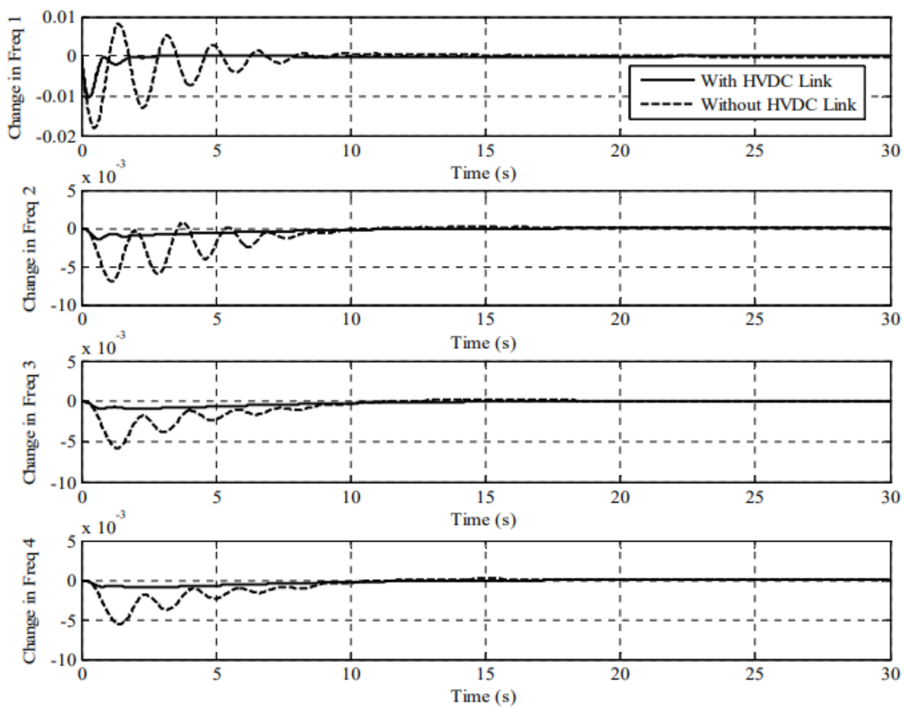

Fig 6: Frequency deviation of area 1to area 4 with ΔPd1 =0.01

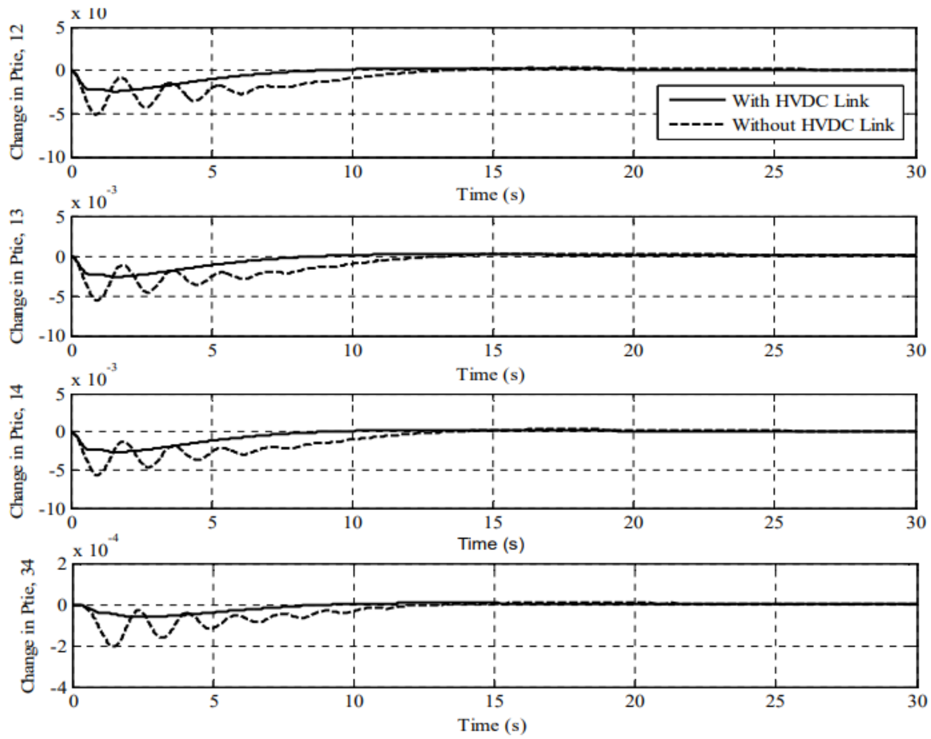

Fig 7: Tie line power deviations with ΔPd1 =0.01

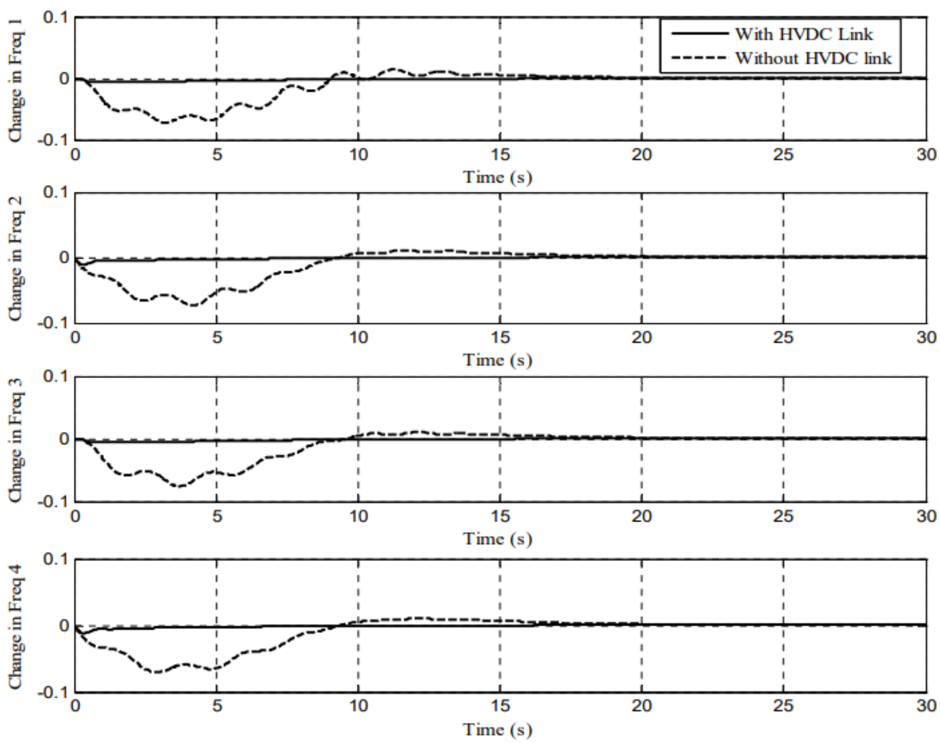

Fig 8: Frequency deviation of area 1 to area 4 with ΔPd2 =ΔPd4 =0.01

Automatic generation control faces the power system as its essential operational issue at present. Due to intense market rivalry electrical utilities need to supply stable reliable power to customers which makes HVDC regulation controllers effective at shortening power oscillations.

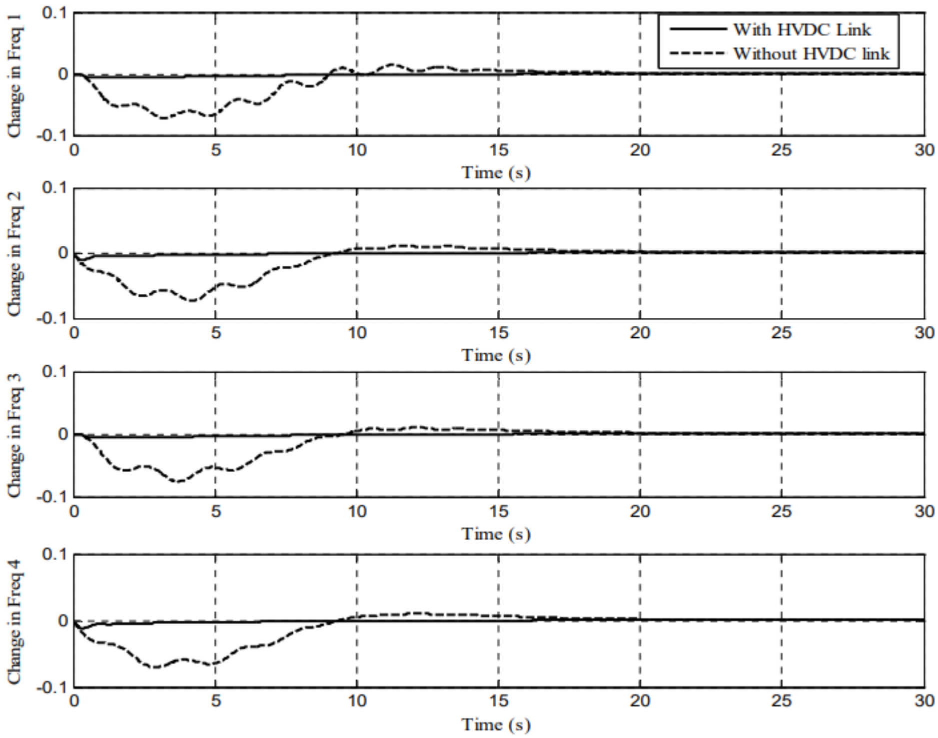

Fig 9: System frequency response with -35 % of nominal values of Bi , Tpsi and Tij with ΔPd1 =0.01

V. Conclusion

The proposed study introduces an HVDC link that operates with an HVAC link to enhance dynamic performance within a linked four region thermal power system. The four-region power system consists of identical thermal reheat turbines operating at a single stage that use GRCs. In-depth studies were performed to analyze system dynamics after load disturbances occur anywhere in the linked power system areas. The analyst develops a fuzzy logic control method through system parameter modifications then evaluates its functionality. When equipped with parallel HVDC links the system shows better results through dynamic standards including settling time and peak overshoot performance. Simulation evidence reveals that high-voltage direct current transmission links help supply consumers with reliable power of superior quality.

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